Partial Cutting in Old-Growth Lodgepole Pine

by Robert R. Alexander

AUTHOR'S PREFACE

This publication supersedes USDA Forest Service Research Paper RM-92, "Partial cutting practices in old-growth lodgepole pine," in which I provided guidelines for initial cutting only. The revisions and improvements to the original are in response to requests by users for information on how stands should be handled after the initial harvest, and for practices needed to obtain natural regeneration after partial cutting. Other changes are the result of greater insight obtained by applying those original guidelines in field studies.

For convenient field use, the stand descriptions and cutting guides in this Research Paper were published separately in a smaller format as Research Paper RM-92A, "Partial cutting practices in old-growth lodgepole pine — Field guide to stand descriptions and cutting practices." Although it contains suggested practices for initial entry only, information in this original Field Guide is still appropriate, and can be used in conjunction with the newer guidelines published here. Copies of RM-92A are available from the Rocky Mountain Forest and Range Experiment Station, 240 West Prospect Street, Fort Collins, Colorado 80521.

Abstract

Guidelines are provided to aid the forest manager in developing partial cutting practices to maintain continuous forest cover in travel influence zones, and in areas of high recreational values or outstanding scenic beauty. These guidelines consider stand conditions, windfall risk situations, and insect and disease problems. These cutting practices may be also used in combination with small cleared openings to create the kinds of stands desirable for increased water yields, improvement of wildlife habitat, and to integrate timber production with other uses. On areas where timber production is the primary objective, clearcutting in small, dispersed units is the recommended method of harvesting trees.

About the cover:

New reproduction established after a light shelterwood cutting in lodgepole pine on the Fraser Experimental Forest, Colorado.

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CONTENTS

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From the silviculturist's point of view, clearcutting is a sound and practical way of bringing mature and overmature lodgepole pine (*Pinus contorta* Dougl.) forests under management, especially when timber production is a major objective. There are several reasons for clearcutting. Since these have been thoroughly discussed by Tackle (1961), they will only be highlighted here:

1. Lodgepole pine, a pioneer species, is shade intolerant and reproduces most satisfactorily when overstory competition is removed or drastically reduced.
2. Dwarf mistletoe (*Arceuthobium americanum* Nutt. ex Engelm.) — present in varying degrees in many mature to overmature stands — is best controlled by separating old and new stands.
3. Windfall, while variable, is always a threat to lodgepole pine forests.
4. The potential for future growth is limited because of the generally low vigor of mature and overmature stands, and the suppressed condition of many of the smaller trees.

Furthermore, many natural stands appear to be even-aged because they developed after fires, or other catastrophic disturbances.

Timber production, however, is only one of the key uses of lodgepole pine forests in the central Rocky Mountains. They occupy areas that also are important for water yield, wildlife habitat, recreation, and scenic beauty. Forest managers must consider how these areas are to be handled to meet the increasing demands of the public. The visual and environmental impacts of clearcutting for timber production are not always compatible with the objectives of other key uses. Described below are the kinds of stands that are desirable for increased water yields, improvement of wildlife habitat, preservation of the forest landscape, and maintenance of scenic values. Silvicultural practices are suggested that can be used alone or in combination with small cleared areas to maintain forest cover while gradually replacing the old stand with a healthy, vigorous new one.

FORM, STRUCTURE, AND ARRANGEMENT OF STANDS FOR KEY USES

Guidelines to aid the forest manager in developing alternatives to clearcutting in spruce-fir forests (Alexander 1973) contain similar descriptions of the kinds of stands desirable for uses other than timber production. They are repeated here for emphasis.

Water

Snowfall is the key to water yield in lodgepole pine forests. Comparisons of cut and uncut plots (8 acres in size), on the Fraser Experimental Forest in Colorado, have shown that more snow accumulated in cutover areas than under adjacent uncut stands. Accumulations were greatest on plots that were clearcut (Wilm and Dunford 1948, Hoover and Leaf 1967). The increased snow depth is not additional snow, however, but a redistribution of snow. Wind transports the snow intercepted on the surrounding trees and deposits it in the openings. Some of the increase in water equivalent in the openings is available, however, for streamflow (Hoover and Leaf 1967).

Research and experience suggest that a round or patch-shaped opening, about five to eight times tree height in diameter, is the most effective for trapping snow (Hoover 1969). In larger openings, wind is likely to dip down to the ground and blow the snow out of the openings. About one-third of the forest area in openings distributed over the watershed appears to be the best arrangement. These openings could either be maintained permanently or regenerated to new growth that would be periodically recut when trees reach about half the height of the surrounding trees. The remaining two-thirds of the area should be retained as continuous high forest, since the taller trees control snow deposition. Trees would be periodically harvested on an individual-tree basis or in small groups (one to two times tree

height) to gradually replace the old with a new stand. Ultimately, the reserve stand would approach a broad-aged structure with the overstory canopy remaining at about the original height.

An alternative would be to make a light cut distributed over the entire watershed, removing about 20 to 30 percent of the basal area on an individual-tree basis or in small groups. The objective is to open up the stand enough to develop windfirmness, and salvage low-vigor and poor-risk trees. Openings five to eight times tree height can then be cut on about one-third of the area. The remaining two-thirds of the area would be retained as permanent high forests, with trees periodically removed on an individual-tree basis or in small groups.

Another alternative that would integrate water and timber production would be to harvest all of the old growth on a watershed with a series of cuts spread over a period of 120 to 160 years. At intervals of about 20 to 40 years, a portion of the area would be harvested in small openings — four to five times tree height — distributed over the watershed. The number of openings cut at each interval would depend on the size of the watershed and the length of rotation and cutting cycle selected. These openings would be regenerated so that at the end of one rotation, the watershed would contain groups of trees in several age classes from reproduction to those ready for harvest. The tallest trees may be somewhat shorter than the original overstory, but the adverse effects on snow deposition should be minimized by keeping the openings small. At the end of one rotation, the forest manager has the option of following the same procedure through the next rotation, or selecting about one-third of the openings to be maintained as snow-trapping areas and converting the remaining area into a broad-aged stand by periodically removing individual trees.

Wildlife

Timber cutting practices affect the use of lodgepole pine forests by Rocky Mountain mule deer (*Odocoileus hemionus hemionus* Rafinesque). On the Fraser Experimental Forest, deer use and abundance and selection of forage species were greater on clearcut openings than under adjacent uncut stands (Wallmo 1969, Wallmo et al. 1972). Openings three chains wide were used more than either wider or narrower openings. Forage production appears to decline about 10 years after cutting, however, as tree reproduction replaces forage species (Wallmo et al. 1972). Similar trends in forage production have also been observed on lodgepole pine clearcuts in Montana (Basile and Jensen 1971). Wallmo suggests that new openings be cut periodically.

One alternative would be to cut about one-sixth of a cutting block every 20 years in openings about four to five times tree height. Each Working Circle would be subdivided into a number of cutting blocks (of at least 300 acres) so that not all periodic cuts would be made in a single year on a Working Circle. Such periodic cutting would provide a good combination of numbers and species of palatable forage plants and the edge effect desired, while creating a several-aged forest of even-aged groups, thus integrating wildlife habitat improvement with timber production.

Natural reproduction established in cleared opening about 5 to 6 times tree height in lodgepole pine on the Fraser Experimental Forest.

Observations on the Medicine Bow National Forest in Wyoming indicate that both natural and cleared openings in lodgepole pine forests are heavily used by American elk [*Cervus canadensis canadensis* (Erxleben) Reynolds] for grazing and calving.[2] The size of opening does not appear to be critical, but openings interspersed with standing timber that can be used for ruminating, resting, and hiding are preferred. Since small openings cut in the canopy are not likely to retain a high proportion of palatable forage species for long periods of time, new openings should be cut when tree reproduction replaces forage species. Another alternative would be to extend the size of the smaller (2 acres or less) natural openings, and periodically harvest the remaining stand under some form of partial cutting.

Other wildlife, including nongame animals, living in lodgepole pine forests are affected by the way these forests are handled. In general, their habitat requirements include a combination of openings and high forests to provide food, cover, and edge. With protection from wildfires many stands have become denser, and reproduction has filled in the openings. Some reduction in stand density is needed to create or improve wildlife habitat. Small, irregular openings (about four to five times tree height) cut in the canopy at periodic intervals would open up the stand and provide the food, cover, and edge needed.

Recreation

Permanent forest cover — at least in part — is preferred in travel influence zones, and in areas of high recreational value and outstanding scenic beauty. Unfortunately, old-growth lodgepole pine stands are not likely to persist in a sound condition indefinitely. Where stand conditions and wind, insect, and disease problems permit, some form of partial cutting is one way that forest cover can be retained while at the same time replacing the old with a new stand. However, the visual impact of logging operations — haul roads, damage to residual trees, and slash and debris — must be minimized. In situations where there is no harvesting alternative to clearcutting, and the environmental impact of clearcutting is unacceptable, there is no choice but to leave the stands uncut.

To reduce the sudden and severe visual impact on the landscape viewer, openings cut in stands for timber and water production, wildlife habitat improvement, and recreation (ski runs) should be a repetition of natural shapes, visually tied together to create a balanced, unified pattern that will complement the natural landscape (Barnes 1971). This pattern is especially important for those openings in the middle and background that can be seen from distant views. The foreground should be maintained in high forests under some partial cutting system (again, where stand conditions and wind, insect, and disease problems permit).

[2] *Personal communication with A. Lorin Ward, Wildlife Biologist, Rocky Mountain Forest and Range Experiment Station, Laramie, Wyoming.*

CHARACTERISTICS OF THE TYPE

The lodgepole pine type is generally pictured as an even-aged, single-storied, overly dense forest, varying in age from place to place but uniform in age within any given stand. This characterization is valid only on those areas where favorable fire, seed, and climatic conditions once combined to produce a substantial number of seedlings (Lexen 1949). Elsewhere, lodgepole pine grows on a wide range of sites with a great diversity of stand conditions and characteristics. This diversity complicates the modification of silvicultural systems for multiple use. Lodgepole pine can occur as two-aged, single- or two-storied stands; three-aged, two- or three-storied stands; and even-aged to broad-aged, multi-storied stands (Tackle 1955). Multi-storied stands, and to a lesser extent two-and three-storied stands, generally resulted from either scattered trees that produced seed for subsequent development of the stand, or from the gradual deterioration of the old-growth associated with "normal" mortality from wind, insects, and diseases. Only rarely do multi-storied stands appear to have originated as uneven-aged stands.

Most ecologists consider the successional status of lodgepole pine to be seral if it is only a temporary occupant of the site. In those situations, stands of mixed overstory composition or with appreciable amounts of advanced reproduction of other species are not uncommon. Pine is ultimately replaced by Engelmann spruce (*Picea engelmannii* Parry) and subalpine fir [*Abies lasiocarpa* (Hook.) Nutt.] at higher elevations, and Rocky Mountain Douglas-fir [*Pseudotsuga menziesii* var. *glauca* (Biessn.) Franco] at lower elevations. On the other hand, many lodgepole pine stands are the result of catastrophic fires, and some areas have burned so often and so extensively that they are nearly pure pine. In those situations, lodgepole pine is maintained on the area as a sub-climax because there is no seed for the normal climax species (Tackle 1961, 1964a).

In stands of pure pine of medium to high density, there is seldom any understory of reproduction, while in low-density stands there may be an understory of young trees. If this reproduction has been suppressed for a long time, it seldom responds to release. Mixed stands can be either 1) pure pine, 2) pine, spruce, and subalpine fir, or 3) pine and Douglas-fir in the

overstory, and the climax species in the understory. Spruce and subalpine fir reproduction suppressed for long periods are able to respond to release and make acceptable growth.

HISTORY OF PARTIAL CUTTING

From the early 1900's to about 1945, timber harvests in the lodgepole pine type on the National Forests of the central Rocky Mountains could generally be described collectively as "partial cutting." The usual procedure was to mark stands for the "selective" removal of special products. Cutting was usually heavy because everything salable was often marked for removal. Nearly 40 years of observation, research, and experience with partial cutting provide some information on the capabilities and limitations of existing stands to maintain permanent high forest cover.

In generaly, heavy partial cutting (removal of more than 50 percent of the total basal area), and under some conditions any kind of partial cutting, was not successful in old-growth stands as a means of arresting stand deterioration. For example, residual trees on the Fraser Experimental Forest suffered heavy mortality when about 60 percent of the total basal area was removed by either individual tree selection or modified seed-tree cutting (Alexander 1966a). Similar results followed heavy partial cutting elsewhere in the central Rocky Mountains, and in the northern and Canadian Rockies (Blyth 1957, Hatch 1967, LeBarron 1952). Even where mortality was not a serious problem, heavy partial cutting often left the older, decadent stands in such poor condition that not only was there little or no growing stock available for another cut, but the stands had little appearance of permanent forest cover (Tackle 1964a).

The principal cause of mortality was usually windfall, and it generally increased as the intensity of cutting increased. Mountain pine beetle outbreaks caused heavy losses in some instances, and beetles continue to be a serious and often unpredictable threat to lodgepole pine forests. In addition, many stands were infected with dwarf mistletoe. Partially opening up the stand intensified the infection on residual trees, which in turn infected the new reproduction. These heavily infected stands are a serious lodgepole pine management problem.

Where substantial reserve volumes were left, partial cutting was successful in some instances in the sense that the residual stand did not blow down. On the Fraser Experimental Forest, windfall losses were light and other mortality negligible after partial cutting removed about 45 percent of the total basal area by a modified shelterwood cut, even though the stands were exposed to windstorms that nearly destroyed adjacent, partially cut stands with less residual basal area (Alexander 1966a). There are also numerous examples of early cuttings on many National Forests in Colorado and Wyoming where a light to moderate shelterwood cut that removed 30 to 40 percent of the total basal area did not result in excessive mortality. The openings created have regenerated to either lodgepole pine or the climax species. Where dwarf mistletoe infection in overstory trees was light, the new pine stand is not heavily infected. Similar stands have originated from open-grown trees, and from stands that were opened up by mountain pine beetle infestations.

SUSCEPTIBILITY TO WIND, DISEASE, AND INSECTS

Windfall

In the central Rocky Mountains, lodgepole pine is generally considered susceptible to windthrow, and the risk increases when the stand is opened up by partial cutting (Alexander 1966a, Mason 1915a). While the tendency to windthrow is frequently attributed to a shallow root system, the development of the root system varies with soil and stand conditions. On deep, well-drained soils, trees have a better root system than on shallow or poorly drained soils. With the same soil conditions, the denser the stand the less windfirm are individual stems, because trees that have developed together in dense stands over long periods of time mutually support each other, and do not have the roots, boles, and crowns to withstand exposure to the wind if opened up drastically. The risk of blowdown is also greater in stands with defective roots and boles. The presence of old windfalls is a good indication of lack of windfirmness. Furthermore, regardless of how stands are cut or the soil and stand conditions, the risk of blowdown is greater on some exposures than others. The following windfall risk situations based on exposure have been identified by Mason (1915b) and Alexander (1964, 1967).

Low Windfall Risk Situations:

1. Valley bottoms except where parallel to the prevailing winds, and all flat areas.
2. All lower and gentle middle north-and east-facing slopes.
3. All lower and gentle middle south-and west-facing slopes that are protected by considerably higher ground not far to windward.

Heavy windfall in lodgepole pine on the Fraser Experimental Forest after partial cutting that removed about 60 percent of the original basal area.

Moderate Windfall Risk Situations:

1. Valley bottoms parallel to the direction of prevailing winds.
2. All lower and gentle middle south- and west-facing slopes not protected to the windward.
3. Moderate to steep middle and all upper north- and east-facing slopes.
4. Moderate to steep middle south- and west-facing slopes protected by considerably higher ground not far to windward.

High Windfall Risk Situations:

1. Ridgetops.
2. Moderate to steep middle south- and west-facing slopes not protected to the windward, and all upper south- and west-facing slopes.
3. Saddles in ridgetops.

The risk of windfall in these situations is increased at least one category by such factors as poor drainage, shallow soils, and defective roots and boles. All situations become *high risk* if exposed to special topographic situations such as gaps and saddles in ridges at higher elevations to the windward that can funnel wind into the area.

Dwarf Mistletoe

Surveys in Colorado and Wyoming show that from 30 to 60 percent of the commercial lodgepole pine forests are infected to some degree by dwarf mistletoe (Hawksworth 1958). Dwarf mistletoe reduces growth and increases mortality (Hawksworth and Hinds 1964, Myers, et al. 1971). It also drastically reduces seed production in infected trees. The mortality rate depends largely on the age of the host tree when attacked. Young trees die quickly, while older trees with well-developed and vigorous crowns may not show appreciable effects for years after the intial infection. Dwarf mistletoe is most damaging in stands that have been partially opened up by cutting, mountain pine beetles, or windfall, and of least consequence on regenerated burns following catastrophic fires (Gill and Hawksworth 1964). Heavily infected old-growth stands frequently have only about half the board-foot volume of comparable uninfected stands (Hawksworth 1958).

The disease is difficult to detect in recently infected stands because trees show no abnormalities except for the inconspicuous shoots on branches and main stems. Where the parasite has been present for a long time, on the other hand, stands will have one or more heavily damaged centers characterized by many trees with witches' brooms, spike-tops, and an above-average number of snags with remnants of brooms (Gill and Hawksworth 1964).

Although optimum development is favored by a vigorous host, and the most vigorous trees in a stand suffer the most damage, the frequency of infection is usually higher on poor than good sites. Furthermore, where site index (Alexander 1966c) is 70 or greater, only the middle and lower crowns of dominants and codominants are susceptible to heavy infection, but trees in the intermediate or lower crown classes are

susceptible to heavy infection throughout their crowns. Where the site index is below 70, all crown classes are susceptible to heavy infection throughout the crowns.[3] In Colorado and Wyoming, dwarf mistletoe has an altitudinal limit about 300 to 500 feet below the upper limit of commercial lodgepole pine forests. This means that in some high areas, considerable lodgepole pine lies in a dwarf mistletoe-free zone (Gill and Hawksworth 1964).

Separation of the old and new stands by clear-cutting and felling unmerchantable residual trees appears to be the best way to control dwarf mistletoe. In areas of high tree values such as recreational, administrative, and homesites, it may be possible to prune infected branches from lightly infected trees, but heavily infected trees must be cut. Partial cutting and thinning generally create ideal conditions for maximum damage and should be avoided where possible unless the infection is light. To quantify the severity of infection, Hawksworth (1961) developed the six-class mistletoe rating system. The average stand rating can be estimated by determining the percentage of trees infected in the stand. The approximate relationship of average stand rating to proportion of trees infected in several mature stands was:

Average stand mistletoe rating	Percent of trees infected
1	50
2	70
3	90
4	97
5	99
6	100

These ratings are used later in this paper under "Modifications of Cutting Practices Imposed by Disease and Insect Problems" to assist in determining which stands might be partially cut without severe damage to the residual trees.

Comandra Blister Rust

This canker disease (caused by *Cronartium comandrae* Pk.) commonly occurs in the central Rocky Mountains, but damage has been most extensive in northern Wyoming (Peterson 1962). Dead tops and flagging branches resulting from girdling are the most conspicuous symptoms (Mielke et al. 1968). The disease cannot pass directly from pine to pine but requires an intermediate host [*Comandra umbellata* (L.) Nutt.].

[3] *Personal communication with Frank G. Hawksworth, Plant Pathologist, Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colorado.*

The damage from Comandra rust is not often spectacular, but trees of all sizes and ages are susceptible (Peterson 1962). Seedlings may be killed in a relatively short time. In older trees, the time between initial infection and death may be 25 or more years because the infection enters the trunk by way of the branches, and the rate of spread is low. Under conditions favorable to the rust, stands may be heavily damaged over limited areas. In those stands, from 30 to 40% of the living and dead trees will have cankers, and about half the cankered trees will have spike-tops (Krebill 1965). Usually, however, the infection is lighter and scattered through the stand (Peterson 1962).

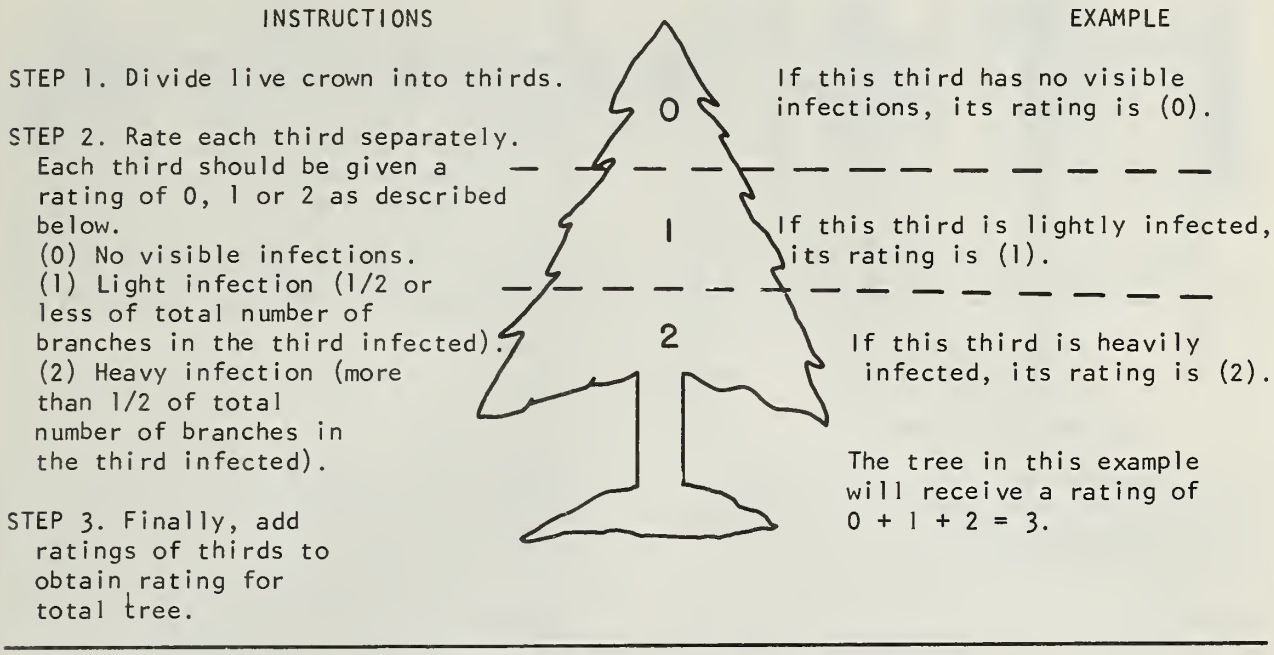
Sanitation salvage cutting is about the only practical way of controlling the disease in forest stands (Mielke et al. 1968). In areas of high tree values it may be possible to prune infected branches from lightly infected trees, but heavily infected trees should be cut. Partial cutting and thinning appear well adapted to the control or reduction of Comandra rust, even in heavily damaged stands, because the disease is not passed from pine to pine and only the trees with stem infections need to be removed.

Western gall rust (*Peridermium harknessii* Moore) occurs on lodgepole pine throughout the Rocky Mountains, but is not as distinctive as Comandra rust because most infections occur as galls on branches rather than on the trunk. Mortality in the seedling stage and loss of growth and cull are the principal forms of damage from this rust. Removal of infected trees in cultural operations is the only practical way to control gall rust damage in forests. Presence of a few galls is not sufficient cause to remove a tree. Only cankered trees need be cut (Peterson 1960).

Mountain Pine Beetle

Many species of insects infest lodgepole pine, but the mountain pine beetle (*Dendroctonus ponderosae* Hopk.) is the most serious insect pest in mature to overmature stands in the Rocky Mountains. Epidemics have occurred throughout recorded history (Roe and Amman 1970), and extensive outbreaks are now in progress in northern Wyoming. Less extensive but severe outbreaks are underway in southern Wyoming and northern Colorado, where a large number of old-growth stands that have been protected from wildfires are now reaching a high degree of susceptibility to attack.

Mountain pine beetles feed and breed in the phloem layer. The first indications of attack are pitch tubes on the trunk where beetles have entered, and boring dust in the bark crevices and around the base of the tree. Trees successfully attacked in the summer usually begin to fade the following spring.



The 6-class mistletoe rating system [Hawksworth 1961].

Needles change from green to yellow green, sorrel, and finally rusty brown before dropping off (McCambridge and Trostle 1972).

Not all stands are equally susceptible to attack. Epidemic outbreaks are usually associated with stands that contain at least some vigorous, thick-phloemed trees 14 inches in diameter and larger (Cole and Amman 1969, Roe and Amman 1970). As the larger trees are killed, the beetles must attack smaller diameter trees, and the outbreak subsides because the phloem of these trees is not thick enough to provide a food supply. Trees smaller than 6 inches d.b.h. are rarely killed.

Natural factors, such as a sudden lowering of fall temperature or prolonged subzero winter temperatures, nematodes, woodpeckers, and parasites, may reduce populations but they cannot be relied upon to control outbreaks (McCambridge and Trostle 1972). Chemical control is expensive and often is only a holding action until potentially susceptible trees can be disposed of by other means. The only alternatives left to the manager in heavily infested stands where most of the trees are 10 inches in diameter and larger are to (1) fell and salvage the infested trees, burn the green culls and unmerchantable portions of trees, and regenerate a new stand, or (2) let the infestation run its course uncontrolled. If infested stands have a good stocking of trees in the smaller diameter classes, on the other hand, partial cutting that removes the vigorous, larger trees with thick phloem appears well adapted to regulating mountain pine beetle losses.

A TREE CLASSIFICATION FOR MARKING IN PARTIALLY CUT STANDS

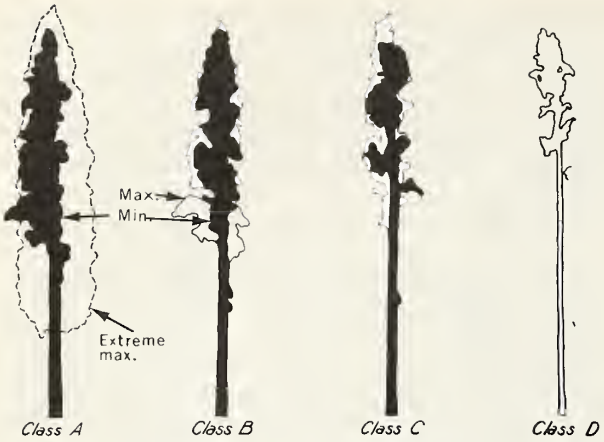
In developing partial cutting practices, knowledge of individual tree characteristics will assist in establishing marking guides. A classification scheme for lodgepole pine in Colorado and Wyoming based on the area, length, and vigor of individual tree crowns (Taylor 1939) is described below:

Vigor class A

1. Crown area: 30 percent or more of the "extreme outline" of vigor class A.
2. Crown length: 50 percent or more of the bole length.
3. Crown vigor: Dense, full, good color, pointed.

Vigor class B

2. Crown area: Usually more than 30 percent but less than 50 percent of the "extreme outline" of vigor class A.
2. Crown length: Usually more than 50 percent but usually less than 60 percent of the bole length.



Tree vigor classes [Taylor 1939].

3. Crown vigor: Moderately dense, good color, pointed or slightly rounded.

Vigor class C

1. Crown area: 15 to 30 percent of the "extreme outline" of vigor class A.
2. Crown length: 40 to 50 percent of the bole length except for trees with above average vigor, when 20 percent of the bole length is sufficient.
3. Crown vigor: Sparse, bunchy, poor color, never pointed.

Vigor class D

1. All live trees of poorer vigor than class C. Includes trees in classes A, B, and C outlines but with dead or dying tops.

Although the classification was developed more than 30 years ago, is subjective, and places many trees of old-growth stands in vigor classes C and D, it nevertheless provides useful guidelines in determining the kinds of trees that should be cut or left, depending on stand, insect and disease conditions, and management objectives.

PARTIAL CUTTING PRACTICES

Shelterwood and group selection cuttings and their modifications are applicable to old-growth lodgepole pine. These regeneration systems harvest the timber on an area in more than one step. From a silvicultural point of view these are the only acceptable options open to the manager where (1) multiple-use considerations preclude clearcutting, (2) combinations of cleared openings and high forest are required to meet the needs of various forest uses, or (3) areas are difficult to regenerate after clearcutting. However, windfall, insects, diseases, and stand conditions which vary from place to place on any area, impose limitations on how stands can be handled. Furthermore, economics of harvesting, manufacturing, and marketing wood products in the Rocky Mountains impose further limits on cutting practices. Cutting to bring old growth under management is likely to be a compromise between what is desirable and what is possible. Management, therefore, is likely to involve several cutting treatments on any one area.

An *accurate appraisal* of the capabilities and limitations of each stand is necessary to determine cutting practices. Furthermore, partial cutting requires *careful marking* of individual trees or groups of trees to be removed, and *close supervision* of logging. The following recommended partial cutting practices are keyed to broad stand descriptions [developed largely by Tackle (1955) for the Intermountain Region and modified for central Rocky Mountain conditions] and windfall risk situations, with the objective of maintaining forest cover for various resource uses. Additional constraints imposed by insect and disease problems are considered near the end of this section. Stands are pure pine unless otherwise indicated.[4] Reproduction less than 4.5 feet tall is not considered a stand story in these descriptions.

Single-Storied Stands

Description

1. Stands may appear to be even-aged, but often contain more than one age class, occasionally may even be broad-aged.
2. Codominants form the general level of the canopy, but the difference in height between dominants, codominants, and intermediates is not as great as in spruce-fir stands.
3. If even-aged in appearance: (a) There is a small range in diameter classes and crown length. (b) Live crown length of dominants and codominants is generally short to medium (30 to 60 percent of the total tree height and boles are generally clear for 10 to 40 percent of total tree height). (c) There are few coarse-limbed trees in the stand.

[4] *In mixed stand, either less than 80 percent of the overstory basal area is lodgepole pine, or the overstory is pine with an understory of a different species.*

Single-storied stand.

4. With two or more age classes, the younger trees usually have finer branches, smaller diameters, longer live crown, and less clear bole than older trees.
5. Stocking is generally uniform.
6. A manageable stand of advanced reproduction is usually absent.[5]
7. In *mixed stands,* the overstory is either (a) pure pine or (b) pine and Engelmann spruce, subalpine fir, or Douglas-fir, with advanced reproduction of species other than pine that may or may not be a manageable stand.

Recommended Cutting Treatments

Single-storied stands are usually the least windfirm because trees have developed together over long periods of time and mutually protect each other from the wind.

Low windfall risk situations.

1. The first cut can remove about 30 percent of the basal area on an indivudal tree basis.[6] This initial entry is a *preparatory cut* that resembles the first step of a three-cut shelterwood, since it probably does not open up the stand enough for pine reproduction to become established in significant numbers. Because overstory trees are all about equally susceptible to blowdown, the general level of the canopy should be maintained by removing some trees in each overstory crown class. The cut should come from trees of C and D vigor classes, but openings larger than one tree height in diameter should be avoided by distributing the cut over the entire area. Furthermore, do not remove dominant trees that are protecting other trees to their leeward if these latter trees are to be reserved for the next cut. In *mixed stands,* if the overstory is pure pine, handle as a pure stand; if the overstory is of mixed composition, cut as much of the basal area recommended in pine as is possible to release the climax species.
2. The second entry into the stand should not be made until 5 to 10 years after the first cut to determine if the stand is windfirm. The second cut should also remove about 30 percent of the original basal area on an individual tree basis. It simulates the second or *seed cut* of a three-step shelterwood. The largest and most vigorous dominants and codominants should be reserved as a seed source in stands with the nonserotinous or intermediate cone habit,[7] but avoid cutting openings in the canopy larger than one tree height in diameter by distributing the cut over the entire area, even if it means leaving trees in the C and D vigor classes with poor seed production potential. In *mixed stands* cut as much of the recommended basal area in pine as is possible without creating openings larger than one tree height.
3. The last entry is the *final harvest* and should remove all of the remaining original overstory. It

[5] *Since any kind of cutting may destroy as much as half of the advanced reproduction, even with careful logging, at least 600 seedlings and saplings per acre of good form and vigor, and free of defect, must be present to be considered a manageable stand.*

[6] *As a practical matter, small trees that do not represent significant competition to the remainder of the stand may be excluded from the computation of the basal area.*

[7] *Lotan and Jensen (1970) classified lodgepole pine trees in the Northern Rockies and Intermountain Region as serotinous if they bore 90 percent or more closed cones, and non-serotinous if they bore 90 percent or more open cones. At least 40 percent of the trees should bear serotinous cones before a stand can be considered to have the closed-cone habit.*

should not be made until a manageable stand of reproduction has become established, but the cut should not be delayed beyond this point if timber production is the primary concern because the overwood (a) hampers the later growth of seedlings, and (b) if infected with dwarf mistletoe, will re-infect the new stand.

4. The manager also has the option of removing less than 30 percent of the basal area at any entry and making more entries, but they should not be made at more frequent intervals. The cut will be spread out and continuous high forest cover maintained for a longer period of time. *This delay is not recommended where mountain pine beetles and dwarf mistletoe impose limitations on how stands can be handled.*
5. The usual uniform arrangement of individual trees in single-storied stands is not well adapted to removing trees by *group selection cutting.* Occasionally, however, natural openings do occur when stands begin to break up. Furthermore, small openings may be desirable to meet management objectives. An alternative to removing trees on an individual basis would be to remove about 30 percent of the basal area in groups. Openings should be kept small, not more than one to two times tree height in diameter; not more than one-third of the area should be cut at any one time. *This kind of cutting should be used only in stands where insect and disease problems are minimal.*
6. The second entry into the stand should not be made until the first group of openings has been regenerated. This cut should also remove about 30 percent of the original basal area without cutting over more than an additional one-third of the area. Openings should be no closer than about one to two tree heights to the original openings.
7. The final entry should remove the remaining groups of merchantable trees. The timing of this cut depends upon the cone habit and how the manager elects to regenerate the openings. If he chooses to use natural regeneration and the stand is classified as nonserotinous or intermediate cone habit, the final harvest must be delayed until the trees in the original groups cut are large enough to provide a seed source.
8. The manager may choose to remove less than 30 percent of the basal area and cut less than one-third of the area at any one time. This will require more entries, but each new cut should not be made until the openings cut the previous entry have regenerated. Furthermore, in stands with nonserotinous or intermediate cone habit, the last groups cannot be cut until there is either an outside seed source or the manager elects to plant these openings.

Moderate windfall risk situations.

1. The first cut should be limited to a light *preparatory* cutting that removes about 20 percent of the basal area on an individual-tree basis. The objective is to open up the stand, but at the same time minimize the windfall risk to the remaining trees. Provision should be made, however, to salvage blowndowns. This type of cutting resembles a *sanitation cut* in that the lowest vigor and poorest risk trees should be removed, but it is important that the general level of the overstory canopy be maintained intact. *Mixed stands* should be handled the same as in low wind risk situations, except that less basal area will be removed.
2. The second entry can be made in about 10 years after the first cut. This entry should remove about 20 percent of the original basal area on an individual tree basis. Windfall that was salvaged after the first cut should be included in the computation of the basal area to be removed. The objective of this *preparatory cut* is to continue to develope windfirmness while preparing the stand for the seed cut. Most of the trees marked for removal should come from the smaller crown and poorer vigor classes, but maintain the general level of the canopy intact. In *mixed stands*, cut as much of the recommended basal area to be removed in pine as is possible.
3. It will require about another 10 years to determine if the stand is windfirm enough to make another entry. This will be the *seed cut* and should remove about 20 percent of the original basal area, including any windfalls since the last cutting. The largest and most vigorous dominants and codominants in *mixed stands*, and pure stands with nonserotinous or intermediate cone habit should be reserved as a seed source, but it is more important to distribute the cut over the entire area.
4. The last entry is the *final harvest*, and it should remove the remaining original overstory. It cannot be made until a manageable stand of reproduction has been established. About 40 percent of the original basal area will be removed in this cut, and if it is too heavy (10,00 bd. ft. or more per acre) to be removed in one harvest without undue damage to the reproduction, the manager must plan on a final harvest in two steps. The second step can begin as soon as skidding is finished in the first step, providing that a manageable stand of reproduction still exists.
5. The manager also has the option of removing less than 20 percent of the basal area at any entry and making more entries, but they should not be made at more frequent intervals.

Two-storied stand.

High wind risk situations.

1. The choice is limited to removing all trees or leaving the stand uncut. Cleared openings can be up to about 5 acres, interspersed with uncut areas. Cutover areas should not exceed about one-third of the total in this risk situation.

Two-Storied Stands

Description

1. Stands may appear to be two-aged, but can contain more than two age classes.
2. Top story — dominants, codominants, and intermediates — resembles a single-storied stand.
3. Second story is composed of younger trees of smaller diameter — small saw logs, poles, or saplings — than the top story, but it is always below and clearly distinguishable from the overstory. Trees in the second story are overtopped and may or may not be suppressed.
4. If more than two-aged, the overstory usually contains at least two age classes. The younger trees are finer limbed and may be smaller in diameter than the older trees. The second story may also contain more than one age class.
5. Stocking of the overstory may be irregular, but overall stocking is usually uniform.
6. A manageable stand of advanced reproduction is usually absent.
7. In *mixed stands*, the overstory is usually pure pine, but occasionally it may be pine with spruce or Douglas-fir. The second story is usually spruce and fir at the higher elevations, and Douglas-fir at the lower elevations.
8. Stocking in *mixed stands* may vary from uniform to irregular.
9. *Mixed stands* may have a manageable stand of advanced reproduction of species other than pine.

Recommended Cutting Treatments

Recommended cutting treatments are the same as for three-storied stands.

Three-Storied Stands

Description

1. Stands may appear to be three-aged, but they contain more than three age classes. Stands are seldom broad-aged, however.
2. Top story resembles a single-storied stand except that there are fewer trees.
3. The second and third stories consist of younger, smaller diameter trees. Second story may be small saw logs or large poles, while the third story is likely to be composed of small poles or saplings. Second and third stories are overtopped, and some trees may be suppressed.
4. Overall stocking is likely to be uniform, but stocking of any story may be irregular.
5. A manageable stand of advanced reproduction is usually absent.
6. In *mixed stands* the top story may be either pure pine or a mixture of pine and other species. The second story is usually spruce and subalpine fir at at the higher elevations, and Douglas-fir at the lower elevations. The second story may occasionally contain some pine, but it is rarely pure pine. The third story is almost always composed of species other than pine.
7. Stocking in *mixed stands* can vary from uniform to irregular.

Three-storied stand.

8. *Mixed stands* often have a manageable stand of advanced reproduetion of species other than pine.

Recommended Cutting Treatments (Two- and Three-Storied Stands)

Trees in the top story are usually more windfirm than those in a single-storied stand. Trees in the seeond and third stories are usually less windfirm than trees in the top story.

Low windfall risk situations.

1. The first eut ean remove up to 50 percent of the basal area in *two-storied* stands (providing not more than half of the basal area removed comes from the top story), and up to 40 pereent of the basal area from *three-storied* stands. This cutting is as heavy as the first or *seed cut* of a two-cut shelterwood, but marking follows the rules for individual-tree selection. Heavier cutting may be possible in three-storied stands, but the appearance of a eontinous overstory is not likely to be retained. Trees removed should be in vigor classes C and D insofar as possible, but since the top story is likely to be more windfirm, seleeted dominants and codominants should be left even when they are in vigor elasses C and D, if they do not have dead or dying tops. Avoid cutting holes in the eanopy larger than one tree height in diameter by distributing the cut over the entire area. Furthermore, do not remove dominant trees that are protecting other trees to their leeward if these latter trees are to be reserved for the next cut. In *mixed stands,* if the top story or, as rarely happens, the first and seeond stories are pure pine, handle as a pure stand. If the top story is of mixed composition, eut as mueh of the basal area to be removed in pine as is possible to release the climax species, but do not eut all of the pine if it is needed to maintain the overstory.
2. The seeond entry should be the *final harvest* to remove the remaining original stand and release the reproduction. It cannot be made until the new stand of reproduction is established. If the residual volume is greater than about 10,000 bd. ft. per acre, the final harvest should be made in two steps to avoid undue damage to newly established reproduetion. The second step ean begin as soon as skidding is finished in the first step, providing that a manageable stand of reproduction still exists.
3. If there is a manageable stand of advanced reproduetion, in *mixed stands,* the first cut ean be an *overstory removal* if the volume is not too heavy. Otherwise, the first eut can remove 40 to 50 pereent of the basal area on an individual tree basis as long as the more windfirm dominants and codominants are left. The timing of the second eut is not eritieal from a regeneration standpoint, providing a manageable stand of reproduction still exists after the first eut and ean be saved.
4. The manager has other options to choose from. He may elect to cut less than the reeommended basal area, make more entries, and spread the cut over a longer period of time by delaying the final harvest until the new stand is tall enough to create the appearance of a high forest. *This option is not recommended where mountain pine beetles and dwarf mistletoe impose limitations on how stands can be handled.*
5. In *pure* or *mixed* stands with irregular stocking that may have resulted from the breakup of single-storied stands, old beetle attacks, or windfall losses, an alternative first cut can remove about 40 percent of the basal area in a modified group selection. The group openings can be larger (two to three times tree height) than in single-

Multi-storied stand.

storied stands, but the area cutover should not exceed about one-third of the total. Openings should be irregular in shape without wind-catching indentations in the borders. *This kind of cutting is not applicable in pure stands where mountain pine beetle or dwarf mistletoe impose limitations,* because the interval between initial cutting and final harvest is likely to be too long to prevent serious mistletoe infection of new reproduction and/or loss of beetle-susceptible trees.

6. Two additional entries can be made in the stand. They should each remove about 30 percent of the original basal area in group openings up to two to three times tree height, but not more than one-third of the area should be cutover at any one time. If there is not a manageable stand of advanced reproduction, the manager must wait until the first group openings are regenerated before cutting the second series. Furthermore, in *mixed* stands, or *pure* stands with the nonserotinous or intermediate cone habit, he must either delay cutting the final groups until there is a seed source or plan on planting these openings. If there is a manageable stand of advanced reproduction, the timing between cuts is not critical from a regeneration standpoint.
7. In *mixed stands* with irregular stocking that contain a manageable stand of reproduction and the volume per acre is not too heavy, the first cut can be an *overwood removal.* If the volume is too heavy for a one-step removal, the manager should follow the recommendations for pure stands because the wind hazard is too great to permit a two-step removal in a stand that has not been previously opened up.

Moderate windfall risk situations.

1. The first entry should be a *preparatory cut* that removes not more than 30 percent of the basal area on an individual-tree basis. Predominants, and codominants and intermediates with long live crowns should be removed first. The remaining cut should then come from trees in vigor classes C and D. Maintain the general level of the canopy by not cutting holes larger than one tree height in diameter in the canopy. Provision should be made to salvage blowdowns. *Mixed stands* should be handled as in low wind risk situations, except that less basal area should be removed.
2. The second entry should not be made in less than 10 years. This cut should remove about 30 percent of the original basal area, including the salvage of any windfalls after the first cut. The second entry is the *seed cut.* The best dominants and codominants should be reserved as a seed source in stands with the nonserotinous or intermediate cone habit, but it is important that the cut be distributed over the entire area.
3. The next entry is the *final harvest* to remove the remaining merchantable volume and release the new reproduction after it has become established. However, if the residual stand has too heavy a volume, the final harvest should be made in two steps.
4. In *mixed stands* that contain a manageable stand of reproduction, and if the volume per acre is not too heavy, the first cut can be an *overwood removal.* If the volume is too heavy for a one-step removal, the manager should follow the recommendations for pure stands because the wind hazard is too great to permit a two-step removal in a stand that has not been previously opened up to develop windfirmness.

High wind risk situations.

1. The choice is limited to either removing all the trees or leaving the stand uncut. Cleared openings

can be up to about 5 acres, interspersed with uncut areas. The cutover area should not exceed about one-third of the total in this risk situation.

Multi-Storied Stands

Description

1. Stand is usually broad-aged with a wide range in diameters.
2. If stands developed from relatively few individuals following disturbance, the overstory trees are coarse-limbed. Fill-in trees are better formed and finer limbed. Vigor of the overstory trees varies from poor to good.
3. In stands that developed from deterioration of single- or two-storied stands, the overstory trees may be no limbier than the fill-in trees. Nearly all of the healthy, faster growing trees are below saw log size.
4. Stocking may be irregular.
5. A manageable stand of advanced reproduction may be present.
6. In *mixed stands,* the overstory may be pure pine or either pine, spruce, and fir at the higher elevations, or pine and Douglas-fir at lower elevations. Understory trees have the same characteristics as pure stands, except that they are likely to be of species other than pine.
7. Stocking in *mixed stands* is more likely to be irregular.
8. *Mixed stands* frequently have a manageable stand of advanced reproduction of species other than pine.

Recommended Cutting Practices

These are usually the most windfirm stands, even where they have developed from the deterioration of single- and two-storied stands. By the time they have reached their present condition, the remaining overstory trees are likely to be windfirm.

Low to moderate windfall risk situations.

1. There is considerable flexibility in harvesting these stands. All size classes can be cut, with emphasis on either the largest or smallest trees in the stand. The first cut can range from an *overwood removal* to release the younger growing stock to a *thinning from below* to improve the spacing of the most vigorous of the larger trees. Thereafter, cutting can be directed toward either even-aged or uneven-aged management. In *mixed stands* the first cut should be an overwood removal of the pine to release the climax species. The understory trees should be thinned to improve spacing.
2. Thinning should be to some specified growing stock level, which will vary with management objectives. Procedures for selecting growing stock levels are outlined by Myers et al. (1971).

High windfall risk situations.

1. The safest first cut is an overwood removal with a light thinning from below to obtain a wider spaced, more open stand that can develop windfirmness. Thereafter, cutting can be directed toward either uneven- or even-aged management.

Modifications of Partial Cutting Practices Imposed by Disease and Insect Problems

Dwarf Mistletoe

1. Cut only in stands where the average mistletoe rating is two or less (70 percent or less of the trees infected), and remove only the percentage of basal area recommended for the stand description and windfall situation. In *single-storied* stands, where site index is 70 or above, trees in the intermediate and lower crown classes should be removed first in preference to dominants and codominants. If site index is below 70, trees in all crown classes are about equally susceptible to infection. In *two-* and *three-storied* stands, as much of the first cut as is possible should come from the second and third stories because these trees are likely to be more heavily infected than the top story. In *single-, two-,* and *three-storied* stands, the final overstory removal can be delayed until the new reproduction is tall enough to provide a forest aspect. To minimize infection of new reproduction, however, the time interval should not exceed 30 years after the *regeneration cut* when the average mistletoe rating is one, or 20 years when the rating is two. Provision should be made to sanitize the young stand at the time of final harvest. In *multi-storied* stands, the safest procedure is an overwood removal with a cleaning and thinning from below.
2. In old-growth stands with an average mistletoe rating of greater than two, any partial cutting, thinning, or cleaning is likely to intensify the infection. The *safest* procedures, therefore, are to either remove all of the trees and start a new stand, or leave the stand uncut. If the manager chooses to make a partial cut for any reason, the

initial harvest should be heavy enough to be a regeneration cut. *All* residual trees must be removed within 10 years after the first cut, and provision made to sanitize the young stand at that time.

Comandra Blister Rust

Cut as many trees with stem cankers and spiketops as possible in the first cut without removing more than the recommended basal area or cutting large openings in the canopy. Since the rate of spread in mature trees is relatively slow and the disease is not transmitted from pine to pine, leaving a few infected trees is less of a risk than opening up the stand too much.

Mountain Pine Beetle

1. If the insect is present in the stand at an endemic level, or in adjacent stands in sufficient numbers to make successful attacks, and
   a. less than the recommended percentage of basal area to be removed in the first cut is in susceptible trees: Any attacked tree and all of the most susceptible trees should be removed in the first cut. This will include most of the trees 12 inches d.b.h. and larger, and all trees 10 to 12 inches d.b.h. in vigor classes A and B. Provision should be made to salvage attacked trees, and the second cut should be made within 10 years of the first cut.
   b. more than the recommended percentage of basal area to be removed in the first cut is in susceptible trees, the manager has three options: 1) Remove all the trees. 2) Remove the recommended basal area in attacked and susceptible trees and accept the risk of future losses. 3) Leave the stand uncut. If the stand is partially cut or left uncut, some trees from 7 to 12 inches d.b.h. and most trees below 7 inches d.b.h. will survive.
2. If the stand is sustaining an infestation that is building up, and the manager chooses to either partially cut or leave the stand uncut, he must accept the risk of an outbreak that could destroy most of the merchantable stand.

Cutting to Save the Residual

In *mixed stands* and to a lesser extent pure stands, the manager must determine whether he has an acceptable stand of advanced reproduction and decide if he is going to manage it before any cutting begins. Furthermore, he must reevaluate the advanced reproduction after the final harvest and slash disposal to determine the need for supplemental stocking. The same criteria used to evaluate advanced reproduction on spruce-fir clearcuts applies here (Alexander 1973).

In partial cutting, protection of the residual from logging damage is of primary concern. The residual includes merchantable trees left after shelterwood cutting, and advanced reproduction in both shelterwood and group selection cutting where an acceptable stand is to be managed.

Protection begins with a well-designed logging plan at the time of the first cut. To minimize damage, skid roads must be layed out — about 200 feet apart depending on the topography — and marked on the ground. These skid roads should be kept narrow, and located so that they can be used to move logs out of the woods at each cut. Close supervision of logging will be required to restrict travel of skidding and other logging equipment to the skid roads.

In shelterwood cuttings, trees should be felled into openings as much as possible using a herringbone pattern that will permit logs to be pulled onto the skid roads with a minimum of disturbance. It may be necessary to deviate from the herringbone felling angle in order to drop trees into openings. If this is the case, the logs should be bucked into short lengths to reduce skidding damage. Trees damaged in felling and skidding should not be removed if they are still windfirm.

In group selection cutting, the felling pattern should be similar where there is a manageable stand of advanced reproduction. Otherwise all trees should be felled into the openings. Both shelterwood and group selection cuttings require close coordination between felling and skidding because it may be necessary to fell and skid one tree before another tree is felled.

Slash Disposal

Some treatment of logging slash and unmerchantable material will probably be needed after each cut. However, treatment should be confined to concentrations and that needed to reduce visual impact, because most equipment now available for slash disposal is not readily adaptable to working in shelterwood cuttings. Furthermore, burning slash will not only cause damage to the residual, but may destroy the seed supply in stands with serotinous cones. Skid out as much of the down sound dead and green cull material as possible for disposal at the landings or at the mill. Treatment in stands should be limited to lopping and scattering, chipping along the roadway, and hand piling and burning to minimize damage. In group selection cutting, if there is not a manageable stand of advanced reproduction, dozers equipped with brush blades can be used to

concentrate slash for burning in the openings. Piles should be kept small to reduce the amount of heat generated. Furthermore, in stands with the serotinous cone habit, treatment should not be attempted until the cones have had time to dry out and open up.

REGENERATION PRACTICES

The primary purpose of the cutting practices suggested are to aid the forest manager in maintaining continuous forest cover of lodgepole pine, while minimizing the limitations to partial cutting imposed by silvical requirements, stand conditions, wind, insects, and diseases.

Nevertheless, the reductions made in the overstory canopy by removing 40 percent or more of the basal area by modified shelterwood, or openings cut in the canopy by modified group selection, are large enough to permit new reproduction to become established, if the seed supply is sufficient and the seedbed provides conditions suitable for germination and survival. Once the new reproduction has become established, the same care in logging and slash disposal suggested for protecting advanced reproduction must be exercised.

Lodgepole pine varies considerably in its cone habit, and each stand should be examined before cutting to determine serotiny. Individual trees generally bear either serotinous or nonserotinous cones; at least 40 percent of the trees should bear serotinous cones before a stand can be considered to have the closed-cone habit.

In general, throughout much of Colorado and southern Wyoming, seed is stored in closed cones that open only when exposed to relatively high temperatures (Alexander 1966b, Tackle 1961). Dispersal comes largely from cones attached to the logging slash or scattered on the ground. How and when the slash is treated directly influences regeneration success.

In northern Wyoming, cones generally open at maturity and seeds are dispersed by the wind in the usual manner. Most seeds will fall within about 200 feet of the source (Boe 1956, Tackle 1964b). In those situations, seed for regeneration comes from trees cut on the area, left standing on the area, or standing around the perimeter.

Scarification is usually necessary to remove heavy concentrations of duff and litter to prepare mineral soil seedbeds; it should be done during logging and slash treatment at the time of the seed cut under shelterwood and at each cut under group selection. Unless 40 percent or more of the ground surface is mineral soil after logging and slash treatment, additional seedbed preparation is needed.

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Keywords: Forest cutting systems, *Pinus contorta*, stand condition, windfall risk, dwarf mistletoe, mountain pine beetle.

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